Multisensor satellite measurements of snow properties on reindeer pastures in North Scandinavian Mountains

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Abstract

Thick ice layers can be formed in mountainous reindeer pastures during melting and refreezing events, and may block the access for reindeer to the reindeer forage lichens as well as important vascular plants. This may lead to starvation and reindeer population declines. We have studied an area in the bordering region between Norway and Sweden, which has a long history as reindeer pastures. We have collected snow measurements in the field, and compared them with Envisat ASAR data, Quikscat Ku-band scatterometer, optical data from MODIS and meteorology data. We find that the SAR data is sensitive to the melting events, and provide excellent spatial information about the distribution of snowmelt. The subsequent refreeze of the snow when temperature drops will some times lead to impenetrable ice layers (3-4 cm). In this study we have searched for signatures of these layers in the remote sensing data.

Background

Reindeer herders are worried about deteriorating conditions for grazing in arctic Scandinavia due to climatic changes. Increased winter temperatures are expected to cause less stable winter conditions at the pastures in the interior of northern Scandinavia. Also more frequent rain-on-ice events with refreezing may block the access to the forage. In order to study this effect Norwegian and Swedish scientists have worked together to document the ongoing change and to provide remote sensing tools for improved monitoring of the reindeer habitat.

Figure 1. Left: Snow pit documentation at reindeer grazing site in April, 2007. Right: Reindeer grazing on snow covered terrain.

Observations

In a series of field campaigns, scientists and the local indigenous people, the samis, have characterized the snow pack in the reindeer grazing areas in terms of both scientific and traditional language. This knowledge base has subsequently been used to interpret the field observations.

We have used Envisat ASAR wideswath data and SeaWinds Quikscat Ku-band data in combination with MODIS data to analyse the snow cover and the snow mass in the study area. An integrated multisensor fractional snow cover system have been developed over years and are now preoperational under the ESA GMES umbrella. For this purpose MODIS is superior as long as clouds are absent. Since clouds are frequent in this area, however, SAR data are used to fill in the gaps. In addition, as a new sensor, Norut is currently exploring the potential to assess the Snow Water Equivalent (SWE) from Quikscat as an additional map layer in the snow service.

Methods

We use different sources of EO data and different techniques to find indicators for the various snow parameters:

Snow cover area fraction: We use data from Terra MODIS and Envisat ASAR data. Data from single sensors are processed individually and fused in a multisensor algorithm with 250 m spatial resolution and daily updates.

Snow wetness: The backscatter difference $\Delta\sigma=\sigma^{current}$ - σ^{ref} between averaged dry snow/bare ground scenes and the current SAR image is used to assess snow wetness. Large areas with $\Delta\sigma$ < -3dB is a clear indication of wet snow. More negative $\Delta\sigma$ is a signature of high snow wetness. This indicator could be used in combination with the air temperature to map areas of potential ice blocking of reindeer grazing areas

Snow water equivalent: To assess the snow water equivalent for the area we use the backscatter difference for the Ku-band channel of Quikscat. We assess the reference backscatter by averaging all available summer Quikscat scenes.. We use a simple relation SWE=1/C ln($\sigma^{current}$ - A_o / σ^{ref} - A_o) for retrieval of SWE. The parameters C=0.02 and A_o =1 are found by regression against snow pillow data from the Norwegian Water and Energy directorate.

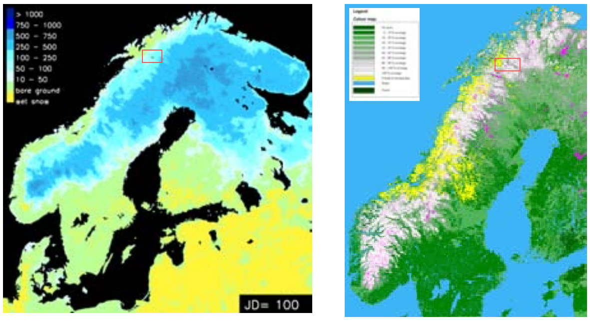

Figure 2. Left: Snow water equivalent observed with the SeaWinds-Quikscat instrument at Ku-band frequency, April 1, 2007. Right: Snow cover area fraction observed with Terra MODIS and Envisat ASAR. Red rectangle indicate study area.

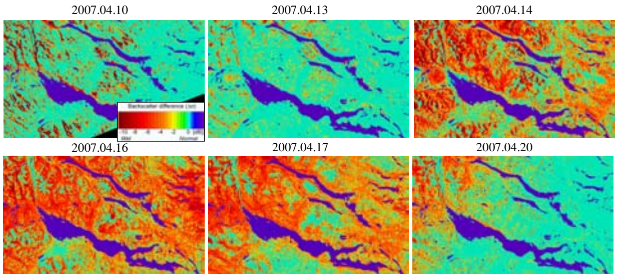

Figure 3. Areas of decreased backscatter from Envisat ASAR gives indications of degrees of snow wetness. Images between April 10 and April 20 in 2007, before, during and after the field campaign. The response to the rain on snow event on April 13-14 is clearly visible.

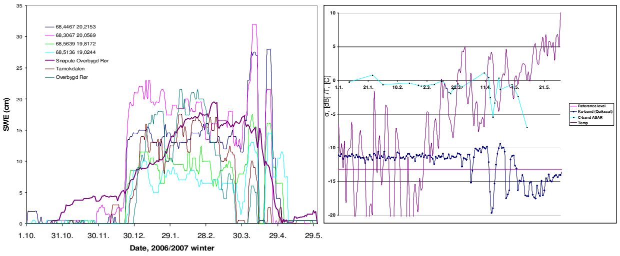

Figure 4. Left: SWE for four pixels in the study area. The SWE from the closest snow pillow in the area is also shown. Right: Average backscatter difference at C- and Ku-band for a 2.25x2.25 km area in the study area. The temperature at a nearby met-station is also shown.

Discussion

By comparing earth observation data, time series of nearby meteorological station and field data, we find that they are over all consistent. Our signatures of wet snow from EO data is consistent with what we experienced in the field and what we would expect from the temperature development during and after the field campaign.

Conclusion

The project has demonstrated that we are able to find relationships between wet snow and the backscatter in SAR imagery. These correlates well with meteorology data. We have also seen that Quikscat Ku-band data contains information about the snow water equivalent. The correlation between SWE from Quikscat and SWE from snow pillow measurements is good. The poor spatial resolution of Quikscat gives, however, larger errors in mountainous terrain. By integrating the data from the various sources in a multisensor, multi-scale service, we hope to be able to provide relevant snow parameters for reindeer herders in the future.

Acknowledgement

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